Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences
Gulf Region
Canadian Science Advisory Secretariat
Science Advisory Report 2006/014

ASSESSMENT OF COD IN THE SOUTHERN GULF OF ST. LAWRENCE

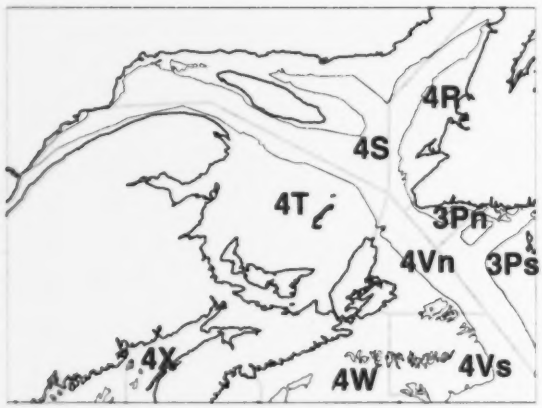

Figure 1: Map of the Gulf of St. Lawrence showing NAFO divisions.

Context

Southern Gulf cod have been exploited commercially since at least the 16th century. Landings varied between 20,000 and 40,000 t annually between 1917 and 1940, and then began to increase to a peak of over 100,000 t in 1958. The fishery was primarily prosecuted with hook and line until the late 1940s, when a ban on otter trawling was lifted. Landings remained relatively high in the 1960s and early 1970s, in the range of 60,000 t. TACs were first imposed in 1974, and these became restrictive as the stock declined in the mid-1970s. The stock recovered somewhat and landings returned to the 60,000 t range during the 1980s. During the 1980s, the fixed gear fishery declined drastically, and the fishery was mainly prosecuted by mobile gear until it was closed in September 1993, due to low abundance. A 3,000 t index fishery was allowed in 1998; catches were 2700 t. A TAC of 6,000 t was in effect from 1999 to 2002. Larger mesh sizes were used in the mobile gear fishery after the re-opening. The directed fishery was closed again in 2003 due to a lack of recovery but re-opened at a TAC of 3,000 t and 4, 000 t in 2004 and 2005 respectively. The management year for the fishery now runs from May 15 of the current year to May 14 of the following year. The management unit for this stock includes all of 4T and catches in 4Vn during November-April. In some years, catches in 4Vs in January-April are attributed to this stock (Fig.1). Assessments of this stock are generally required on an annual basis and the results form part of the information base used to establish the TAC.

SUMMARY

- In 2005-2006, the TAC was 4,000 t. As of December 31, 2005, 2,815 t had been landed.
- Current abundance indices indicate that stock status has not changed markedly over recent years. The 2005 points in the research vessel and both sentinel surveys are the lowest in the series .

Canada

- Abundance is low and spawning stock biomass is estimated to be at the lowest observed level since 1950. The current estimate of spawning stock biomass is about 55,000 t at the beginning of 2006, similar to 2005 biomass.
- Spawning stock biomass is estimated to be well below the limit reference point for this stock (80,000 t). Below the limit reference point, a stock is considered to have suffered serious harm because the probability of poor recruitment is high.
- Year-classes in the 1990s are estimated to be below average. Some recent year-classes (1998-2000) are estimated to be amongst the lowest on record.
- The 2001 and 2002 year-classes are estimated to be larger than the ones produced in the preceding several years but the first estimate of the 2003 year-class is very low.
- Natural mortality remains high (about 0.4). Fishing mortality in 2005 was 0.07.
- If landings in 2006 are similar to those in 2005 then there is about a 67% probability of some decline in spawning stock biomass. At that level of catch, the estimated decline in spawning stock biomass would be about 1%.
- At the current high natural mortality rates and low growth rates, rebuilding of spawning stock biomass will require improved recruitment and low catches.
- Given the current stock status, the application of the precautionary approach would require that removals in 2006 be set at the lowest possible level.

BACKGROUND

Species Biology

Atlantic cod (*Gadus morhua*) is a demersal fish species which occurs on both sides of the North Atlantic. Southern Gulf of St. Lawrence cod are relatively long lived, and may reach ages of 20 or more when mortality is low. Cod from the southern Gulf of St. Lawrence are relatively slow growing compared to other cod populations. Individual fish growth is estimated to have declined in the late 1970s and has remained low since. They begin to reach commercial size (43 cm) at about age 5, and are fully available to the commercial fishery by age 8. They start to mature at a size below the commercial size of 43 cm (ages 4-5) and by age 7 most fish in the population are sexually mature. It is estimated that the natural mortality of southern Gulf of St. Lawrence cod increased in the mid-1980s.

Southern Gulf cod are highly migratory. Spawning occurs in the Shediac Valley and around the Magdalen Islands from late April to early July. During the summer, the cod are widely distributed while they feed heavily on krill, shrimp, and small fish, primarily herring, American plaice, and capelin. The fall migration begins in late October and cod become concentrated off western Cape Breton in November as they move into 4Vn. The stock overwinters in 4Vn and northern 4Vs, along the edge of the Laurentian Channel. The return migration usually begins in mid-April, although this can be delayed by the late breakup of winter ice.

The Fishery

A TAC of 4,000 t was in place for 2005-2006. This included an allowance of 200 t for sentinel and scientific surveys. Cod were caught in cod-directed fisheries and as by-catch in fisheries directed at other species, mainly flatfish. Directed fisheries for cod were closed before June 24, 2005. By-catch of cod in other fisheries was restricted to between 5 and 25% depending on the target species. As in the last few years, the recreational fishery was prohibited.

Table 1: Landings and TACs (thousands of tonnes) for southern Gulf of St. Lawrence cod.

Year	Average 1981 - 1990	Average 1991 - 1995	Average[1] 1996 - 2000	2001	2002	2003	2004	2005[2]
Landings	60.8	19.7	3.6	5.8	5.1	0.3	2.3	2.8
TAC	57.5	20.8	2.4	6.0	6.0	0	3.0	4.0

1. Including the allowance of 3000 t for an index fishery in 1998.
2. Preliminary data
(Note: starting in 1999, TAC for May 15 to May 14 of the following year.)

The total reported **landings** were 2,815 t in 2005 (Table 1, Fig. 2). Catches in the cod-directed and by-catch fisheries amounted to 2,713 t. Catch reporting in the commercial fishery is considered reliable. The TAC was not reached because little effort was directed for the 4Vn allocation, in part due to market conditions including low prices, and some other allocations were not reached (e.g. French reserve, sentinel allocation). Catches from January 1 to May 14 2006 are expected to be less than 1% of landings in 2005.

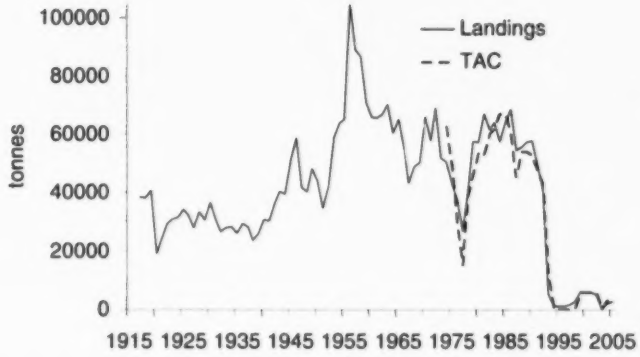

Figure 2: Landings and TAC (t) for the southern Gulf of St. Lawrence cod stock.

Sentinel surveys that are used to obtain additional indices of abundance of the stock caught 102 t. As in recent years, the fishery in 2005 was concentrated close to shore in the Miscou Bank – Shediac Valley area, north shore of PEI, western shore of Cape Breton and the edge of the Laurentian Channel near 4Vn.

The dominant age-groups in 2005 landings were ages six to nine. Overall, in 2005, the **average weights** at age of cod in the catch and in the annual research vessel survey declined and are low relative to the period before 1980 (Fig. 3).

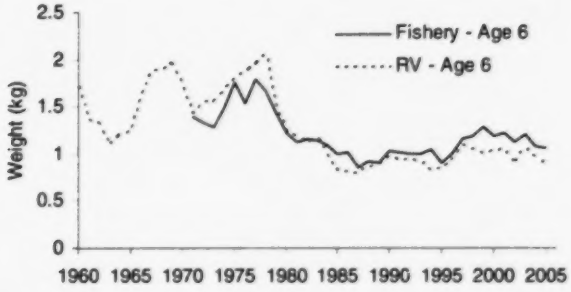

Figure 3: Average weight (kg) of age 6 cod in fishery catches and from the research survey.

ASSESSMENT

Stock Trends and Current Status

The information used in this assessment includes the annual research vessel survey (1971-2002, 2004-2005), landings data from 1917-2005, commercial catch information from 1950-2005, sentinel survey data from 1995-2005, otter trawl catch rate data from 1982-1993, and the views of industry expressed in the annual telephone survey from 1997-2002 and 2004-2005.

The **views of fishers** on the state of the resource were obtained through a telephone survey of active cod fishers in 2005. Of the 138 fishers interviewed who indicated that cod was their first priority, 32% felt that the status of the stock was higher or much higher when compared to 2004, while 20% considered the 2005 cod abundance to be lower or much lower than in 2004.

Thirty-sever percent thought that the abundance of cod was about the same and the remainder had no opinion. Interviewed fishers continue to be positive about stock abundance but less so than in previous years (Fig. 4). The majority of fishers who indicated that cod was their second priority thought that abundance of cod was the same or lower than in 2004.

In 2005, cod **catch rates** for 13 groundfish seiners involved in the commercial fishery since 1999 were not significantly different than those of previous years (Fig. 5). These catch rates do not suggest any improvement in stock status in the last two years.

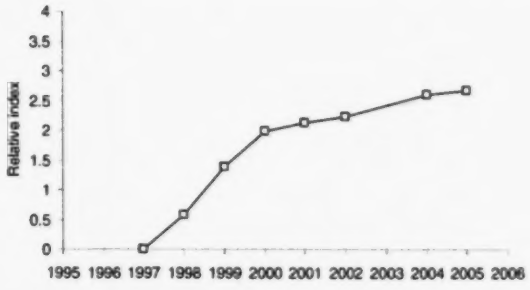

Figure 4: Relative index of cod abundance based on the opinion of fishers who indicated cod as first priority.

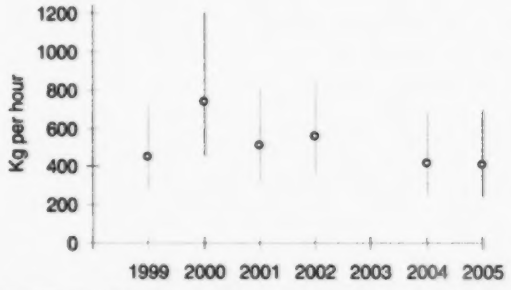

Figure 5: Seiner catch rates (kg/hour). Vertical bars indicate approximate 95% confidence intervals.

The annual **resea**rch vessel (RV) survey has been conducted in September since 1971. The survey index indicates that the abundance of cod was low in the early to mid-1970s then

increased to the early 1980s. Abundance was high until the late 1980s but declined rapidly to low levels by 1992. With the closure of the fishery in 1993, the decline was arrested but the abundance index has remained low.

There have been changes in the research vessels used in recent years for the survey. In 2003, the *CCGS Alfred Needler* was replaced by the *CCGS Wilfred Templeman*. Because no comparative fishing experiments were conducted, the results in 2003 were not used here as an indicator of stock status. Starting in 2004, the *CCGS Teleost* was employed for the survey using the same Atlantic Western IIA trawl used previously. In both 2004 and 2005, comparative fishing experiments were conducted between the *CCGS Teleost* and the *CCGS Alfred Needler* while conducting the annual survey. The analysis of paired fishing sets by the two vessels indicated no significant difference in catchability between these two ships for cod in the southern Gulf. Data from both vessels have been used to calculate the abundance estimates for 2004 and 2005.

The 2005 estimates of abundance were the lowest seen in the time series (Fig. 6). This suggests that stock abundance has remained low. Survey mean weight per tow also indicates that stock biomass has remained low since 1993.

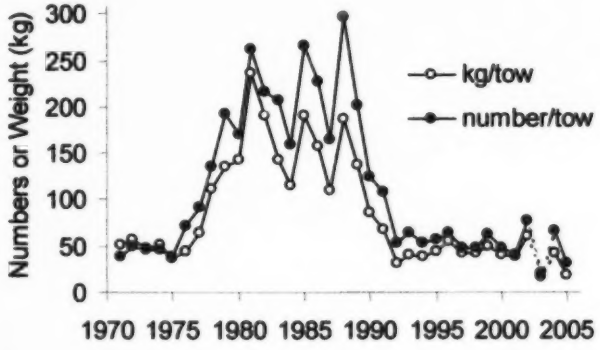

Figure 6: September research survey abundance indices for cod 2 years and older (2003 is not considered a comparable indicator).

In 2004, the abundance of cod aged two and three years was significantly higher than that observed in the surveys conducted in the several years prior to 2003. These fish are the 2001 and 2002 year classes and in the 2005 survey, they accounted for almost half of the estimates in numbers.

During the 2005 survey, cod were found slightly further offshore from the east coast of New Brunswick than in recent years; however, the geographic distribution of cod was mostly consistent with that observed in recent years. Highest concentrations were found in the Shediac Valley, the north coast of PEI, east of the Magdalen Islands and in the area between the Magdalen Islands and Cape Breton (Fig. 7).

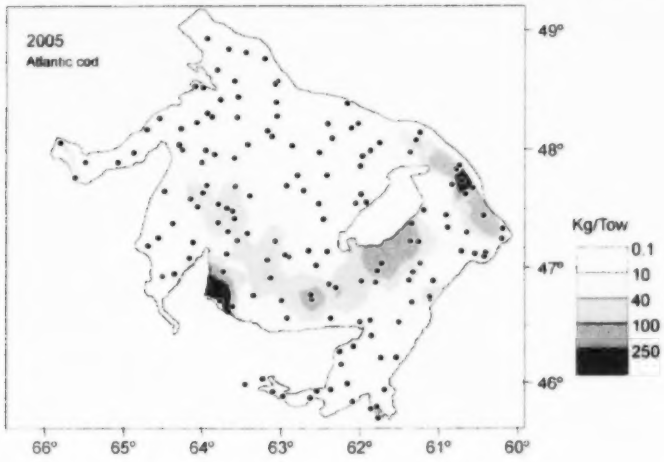

Figure 7: Distribution of cod (kg per set) in the September 2005 research survey.

The sentinel survey program was continued in 2005. Two types of surveys are conducted: a trawl survey in August and a sentinel longline survey from July to November. The synoptic **sentinel trawl survey** was started in 2003. Estimates of abundance and biomass from the trawl survey were lower than those observed in 2003 and 2004 (Fig. 8).

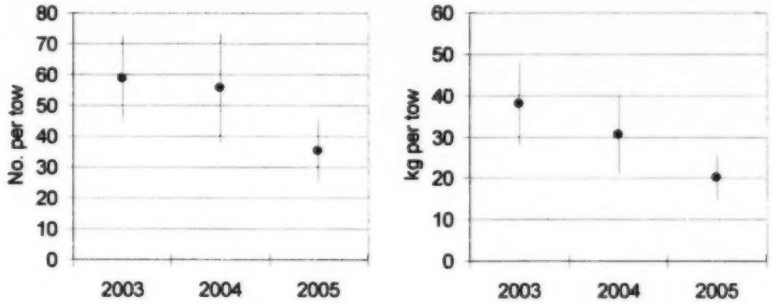

Figure 8: August sentinel trawl survey indices. Vertical bars indicate approximate 95% confidence intervals.

The length frequency distribution in the sentinel trawl survey was relatively similar to that obtained in the September research vessel surveys when accounting for within-year growth (Fig. 9). Fewer fish less than 20 cm were caught in the sentinel survey owing to the larger mesh size of the liner used in the sentinel trawl. Ages 3 to 5 were important in the age composition of cod caught in the sentinel trawl survey, as was the case in the research survey (Fig. 10).

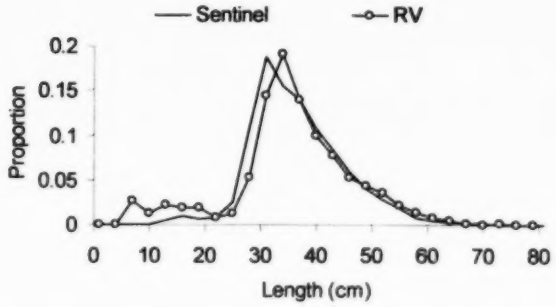

Figure 9: Length frequency distribution of cod caught in the August 2005 sentinel trawl survey and the September 2005 research vessel survey.

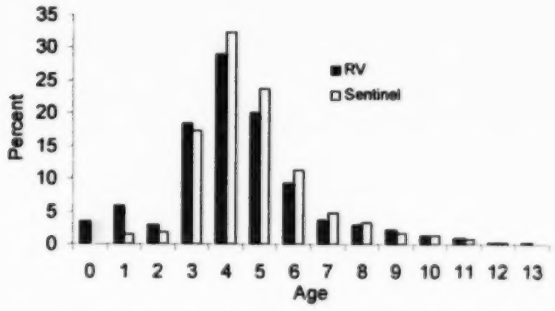

Figure 10: Age composition of cod caught in the August 2005 sentinel trawl survey and the September 2005 research vessel survey.

As did the September research vessel survey, the sentinel trawl survey indicated a geographic distribution that was slightly further offshore from the coast of New Brunswick than observed in previous years. Highest concentrations were located east of Shediac Valley, off the north coast of PEI, and in the area between the Magdalen Islands and Cape Breton. Concentrations were also found near the Gaspé Peninsula (Fig. 11).

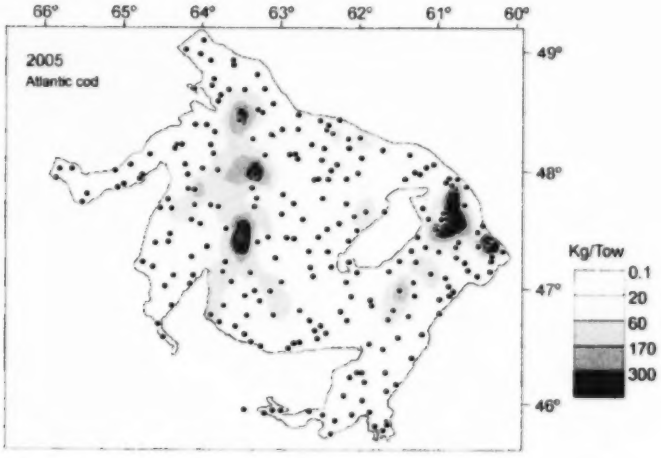

Figure 11 : Distribution of cod (kg per set) in the August 2005 sentinel trawl survey.

The **sentinel longline survey** resulted in a catch of 96 t. Eighteen vessels fished at 40 reference sites. Standardized catch rates were slightly lower than in 2004 but not significantly so (Fig. 12). Overall, catch rates appear to have declined marginally since the late 1990s and suggest that there has not been a major change in population biomass. As in recent years, sentinel catch rates for fixed gears near PEI tended to be higher than in other areas.

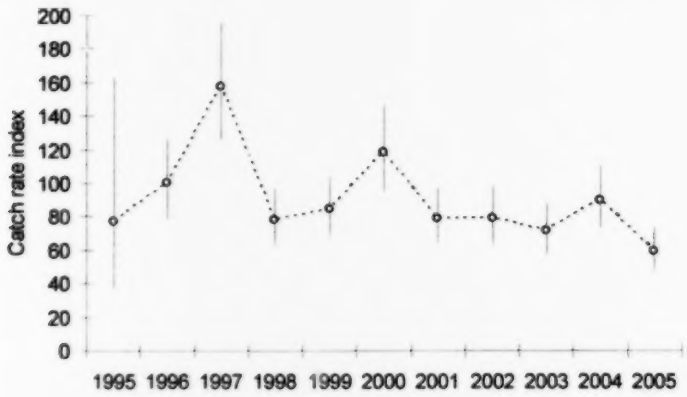

Figure 12: Longline sentinel catch rate index. Vertical bars indicate approximate 95% confidence intervals.

In summary, current abundance indices indicate that stock status has not changed markedly over recent years, although the 2005 index is the lowest point in the series.

Previous work has indicated an increase in the **natural mortality** rate (*M*) of this cod stock. This would include unaccounted mortalities due to factors such as poor environmental conditions, predation, unreported catches and changes in life history characteristics.

Total mortality estimates from survey data continue to be high. Estimates of natural mortality from population analyses also suggest that *M* has not declined appreciably since the late 1980s. Consequently, the assumptions for *M* were the same as those used in previous assessments. *M* for all age groups was set at 0.2 from 1971 to 1985 and 0.4 from 1986 to 2005.

The contribution of each of the various potential causes of the recent high estimates of *M* is undetermined. Consumption estimates of cod by grey and harp seals in 2000 for this stock range from 19,000 to 39,000 t (all ages) depending on diet assumptions. The higher estimates were produced using diet compositions from outside the stock area.

Cod consumption by grey seals is estimated to exceed that by harp seals in the southern Gulf. Although diet samples suggest that most cod consumed by seals appear to be less than 35 cm in length, diet analyses cannot account for cod that may be killed but not consumed totally (heads are not eaten). Changes in natural mortality estimates for cod are consistent with trends in grey seal abundance in the southern Gulf of St. Lawrence.

Total (ages 3 and older) and spawning stock biomass, derived from a **population model**, were high in the 1950s, but declined throughout the 1960s and reached a minimum in the mid-1970s (Fig. 13). There was a sharp increase in spawning biomass with the recruitment of strong year-classes (1974-75, 1979-80), but then declined rapidly, reaching a low in 1993 (Fig. 13).

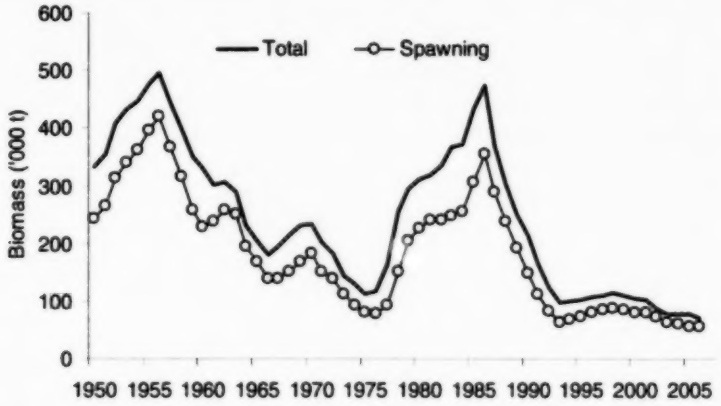

Figure 13: Total and spawning stock biomass estimates derived from the population model for cod in the southern Gulf of St. Lawrence.

Spawning stock biomass has been low since the early 1990s and has declined since 2001. The estimate of spawning stock biomass at the beginning of 2006 is 55,000 t. The current estimate of the spawning biomass in 2005 is lower than the estimate produced in the last assessment (66,000 t). In addition to the decline in abundance indices in 2005, a reduction in the average weight of cod at age is also responsible for the change in the estimates of stock biomass.

The trend in total abundance (Fig. 14) is similar to that of spawning biomass (Fig. 13). However, spawning biomass was lower in the 1980s than the 1950s due to lower weights at age. Abundance remains low but increased somewhat in 2004 and 2005 because the 2001 and 2002 year-classes are more abundant than those of the preceding several years. The estimate of the incoming age 3 (2003 year-class) is low, which results in a decline of abundance for the beginning of 2006.

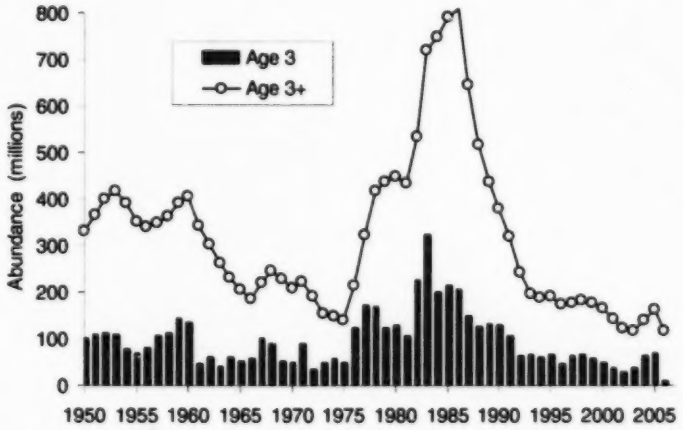

Figure 14: Population abundance (ages 3+) and recruitment estimates for southern Gulf of St. Lawrence cod.

It is noted that, with the addition of the data collected in 2005, the estimate of the abundance of the 2002 year-class has been significantly revised downwards compared to the last assessment of the stock.

Recruitment of year-classes produced in the late 1980s and throughout the 1990s are significantly below the long–term average of about 96 million fish at age 3. The 1998-2000 year-classes are estimated to be amongst the lowest on record. The 2001 and the 2002 year-class are estimated to be more abundant but the estimate of the 2003 year-class is very low. This is the first estimate of this year-class and the uncertainty is large.

Analyses indicate that the high production of recruits in the mid to late 1970s may have resulted from the low abundance of pelagic fish species (herring and mackerel). Herring and mackerel feed on small prey including the early life stages of cod (eggs and larvae). Pelagic fish biomass (particularly mackerel) is expected to be very high over the next few years.

The exploitation rate of commercial fisheries on southern Gulf cod increased from the early 1950s to the mid-1970s, with the exception of a high value in 1959 (Fig. 15). There was a slight decrease in 1977 and 1978 with the extension of fisheries jurisdiction. The exploitation rate increased again and averaged near 30% up to 1988. The exploitation rate then increased sharply and reached near 60% in 1992. Fishing effort was reduced markedly in 1993 with the closure of the directed fishery. Exploitation rates during the moratorium ranged between one and three percent. In 2005, the exploitation rate was estimated at about 6% (F=0.07).

Figure 15: Exploitation rate (ages 7+) for southern Gulf of St. Lawrence cod.

Sources of Uncertainty

The estimate of natural mortality in recent years remains a source of uncertainty in the assessment. Predation by seals is considered to be a significant component of natural mortality and analyses suggest that changes in natural mortality are consistent with grey seal abundance trends. Recent analyses indicate that seal predation is higher than previously estimated; however, there is considerable uncertainty about seal diets in the southern Gulf. Diet analyses rely on the presence of hard parts from prey species in seal stomachs. Conclusions about diet composition would be affected if seals tend not to eat the heads of larger cod.

The lack of survey data for 2003 introduces uncertainty in recent abundance trends. The estimates of recent year-classes (2002 and 2003) are uncertain as they are based on few observations. However, these year-classes will not contribute significantly to the fishery or the spawning biomass until 2007 and 2008.

CONCLUSION AND ADVICE

The productivity of the stock has been low for more than a decade because of poor growth and high natural mortality. The estimates of the 1998, 1999 and 2000 year-classes are amongst the

lowest on record. While the estimates of the 2001 and 2002 year-classes are higher, the first estimate of the 2003 year-class is very low. The outlook for the stock is thus more pessimistic than in the previous assessment and does not suggest significant improvement in the short term.

Projections at various levels of catch in 2006 are provided (Fig. 16). These estimates were made using the best available point estimates of stock size. The estimate of the 2003 year-class was also used. Although there is a high level of uncertainty associated with this estimate, only a small fraction of this age group contributes to spawning stock biomass. For any catch in 2006, the associated exploitation rate is determined by reading up to the dotted line, then across to the left side. The percent change in spawning stock biomass can be determined by reading up to the solid line then across to the right side.

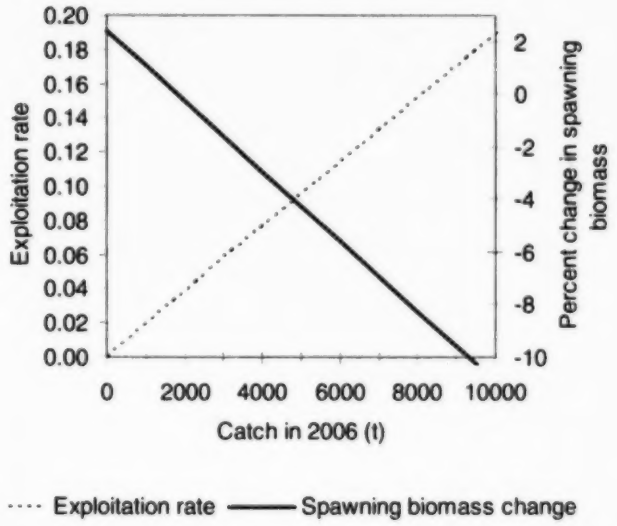

Figure 16: Estimates of exploitation rate and spawning stock biomass changes for various levels of catch in 2006.

It is estimated that the spawning biomass will increase by about 2% if there is no catch in 2006. Catches of 2,000 t in 2006 would result in no change in spawning stock biomass. Higher catches would result in some decline.

It is also possible to estimate the uncertainties regarding stock size and then use these in **risk analyses**. The risk analyses considered were: a) the probability that the 2007 spawning biomass would be less than the 2006 biomass, b) the probability that the spawning biomass would not increase by at least 5% from 2006 to 2007 and c) the probability that the spawning biomass would decline by 5% from 2006 to 2007. These risk analyses include uncertainties in the population estimates but not those associated with natural mortality, weight at age, and partial recruitment. It should be noted that risk was calculated for the calendar year, whereas TACs for this stock are set for the period 15 May to 14 May.

There is a 12% probability that spawning biomass will decline during 2006 with no catch. If the catch in 2006 was the same as in 2005 (2815 t), there is about a 67% probability of a decline (Fig. 17). At that level of catch, the point estimate of the decline in spawning stock biomass would be about 1%. Thus, in order to minimize the risk of further declines, it would be advisable to limit catches to the lowest level possible.

The current spawning stock biomass is sufficiently depressed that the chance of obtaining good recruitment is greatly reduced. This could pose a risk of serious harm to the stock. Analyses for this stock indicated that the chance of obtaining good recruitment is reduced when spawning stock biomass is below about 80,000 t (limit reference point). The current estimate of spawning stock biomass (55,000 t) is well below the limit reference point and the stock is considered to have suffered serious harm because the probability of poor recruitment is high. Given the current stock status, the application of the precautionary approach would require that removals in 2006 be set at the lowest possible level.

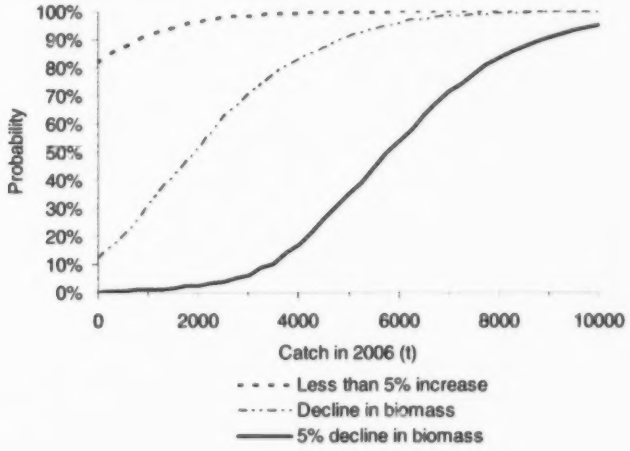

Figure 17: Risk analyses at various levels of catch in 2006.

At the current high natural mortality rates and low growth rates, rebuilding of spawning stock biomass will require improved recruitment and low catches. The chance of substantially improved recruitment may be low given the high pelagic biomass and low cod spawning stock biomass. If rebuilding does occur, it is likely to be very slow. If current conditions persist, very little increase in spawning biomass can be expected and further declines are possible.

SOURCES OF INFORMATION

Benoît, H.P. 2006. Standardizing the southern Gulf of St. Lawrence bottom-trawl survey time series: Results of the 2004-2005 comparative fishing experiments and other recommendations for the analysis of the survey data. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/008.

Chouinard, G.A., and A. Fréchet. 1994. Fluctuations in the cod stocks of the Gulf of St. Lawrence. ICES Mar. Sci. Symp. 198: 121-139.

Chouinard, G. A., D. P. Swain, M. O. Hammill, and G. A. Poirier. 2005. Covariation between grey seal (*Halichoerus grypus*) abundance and natural mortality of cod (*Gadus morhua*) in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 62:1991-2000.

Chouinard, G.A., L. Currie, G.A. Poirier, T. Hurlbut, D. Daigle, and L. Savoie. 2006. Assessment of the southern Gulf of St. Lawrence cod stock, February 2006/ Évaluation du stock de morue du sud du Golfe du St-Laurent, février 2006. DFO Can. Sci. Adv. Sec. Res. Doc. 2006/006.

Hammill, M.O., and G.B. Stenson. 2002. Estimated consumption of Atlantic cod (*Gadus morhua*) and some other prey by grey seals (*Halichoerus grypus*) and harp seals (*Phoca groenlandica*), in the southern Gulf of St. Lawrence (NAFO Division 4T). DFO Can. Sci. Adv. Sec. Res. Doc. 2002/054.

Poirier, G. A., and L. Currie. 2006. Results from the August 2005 sentinel mobile survey of the southern Gulf of St. Lawrence. DFO Can. Sci. Adv. Sec. Res. Doc. 2006/009.

Sinclair, A.F. 2001. Natural mortality of cod (*Gadus morhua*) in the southern Gulf of St. Lawrence. ICES J. Mar. Sci. 58: 1-10.

Swain, D.P., and A.F. Sinclair. 2000. Pelagic fishes and the cod recruitment dilemma. Can. J. Fish. Aquat. Sci. 57: 1321-1325.

FOR MORE INFORMATION

Contact: Ghislain Chouinard
Fisheries and Oceans Canada
Gulf Fisheries Centre
P.O. Box 5030, Moncton
New Brunswick E1C 9B6
Tel: (506) 851-6220
Fax: (506) 851-2620
E-Mail: Chouinardg@dfo-mpo.gc.ca

This report is available from the:

Maritimes Provinces
Regional Advisory Process
Department of Fisheries and Oceans
P.O. Box 1006, Stn. B203
Dartmouth, Nova Scotia
Canada B2Y 4A2

Phone number: 902-426-7070
Fax: 902-426-5435
e-mail address: XMARMRAP@mar.dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

ISSN 1480-4913 (Printed)
© Her Majesty the Queen in Right of Canada, 2006

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

DFO, 2006. Assessment of Cod in the Southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/014.